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Title: METHOD AND APPARATUS FOR CONCENTRATING A
GAS USING A SINGLE STAGE ADSORPTION ZONE

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Title: METHOD AND APPARATUS FOR CONCENTRATING A GAS USING A SINGLE STAGE ADSORPTION ZONE

5 This application is a continuation-in-part application of application no. 09/240,618, filed on February 1, 1999.

FIELD OF THE INVENTION

A This invention relates to a method and apparatus using a single ^{adsorption} ~~absorption~~ zone for producing an enriched stream of a first gas from a stream containing the first gas and at least one second gas. In one embodiment, the method and apparatus may be used to obtain a concentrated stream of oxygen from air.

BACKGROUND OF THE INVENTION

15 Various different methods have been developed for separating gases and producing a concentrated stream of a selected gas. One particular method which has been used in industry is the pressure swing adsorption process. Generally, these processes use an adsorbent which, under elevated pressure conditions, preferentially
20 adsorbs a targeted gas over other gases present in a gas stream. Accordingly, the adsorbent could be selected to preferentially adsorb an undesirable gas from a gas stream thereby leaving a gas stream having an increased concentration of the ^{gases} ~~gases~~ remaining in the gas stream. An example of such a process would be the use of a
25 pressure swing adsorption process to produce an oxygen enriched air stream. The adsorbent would be selected to preferentially adsorb nitrogen over oxygen. Thus, after the adsorption process is conducted, the pressurized air in contact with the adsorbent contains a higher percentage by volume of oxygen. This oxygen
30 enriched air may then be vented from the adsorption zone and the adsorbent purged (at reduced pressure conditions) to remove the adsorbed nitrogen. Alternately, such a process may be used to preferentially adsorb a targeted gas (e.g. oxygen) thereby also producing an enriched stream of oxygen.

35 Various different processes have been designed to

A utilize the selective ^{adsorption} ~~absorption~~ ability of zeolite. Examples of these include, Bansal (United States Patent Number 4,973,339), Stanford (United States Patent Number 4,869,733) and Haruna et al (United States Patent Number 4,661,125).

5 The process and apparatus of Bansal, Stanford and Haruna et al each utilize two adsorption zones. The use of two adsorption zones is undesirable as it unnecessarily complicates the apparatus since it requires additional valving and control means to cycle each adsorption bed through a pressurization cycle and a
10 purging cycle. Further, this adds to the cost of the apparatus and decreases the reliability of the apparatus.

Other disadvantages of existing designs is the requirement to use expensive valve control means. In particular, solenoids are frequently required to switch the adsorption zone
15 from a pressurization mode to a purging mode. These controls are expensive and also prone to failure after extensive use.

Further, existing designs utilize electronics (e.g. micro-processors) to control the cycling of the adsorption zone. This adds to the cost of the equipment and also requires an electrical power
20 source to operate the process. Further, the electronic components may be damaged in harsh environments and this limits the applications of ~~the~~ some existing designs.

SUMMARY OF THE INVENTION

25 According to the instant invention, the pressurization of a member such as a storage container for a portion of the concentrated ^{gas} may be used to actuate the purging cycle when the storage container pressurizes to a desired level. Accordingly, an electronic controller is not required to time the process. Further, no
30 gas sensors are required to determine when to actuate a particular part of the cycle of the adsorption zone.

5 A further advantage of the instant invention is that the pressure actuatable member may be drivingly linked to the purge valve. In this embodiment, simple actuation means may be used to move the purge valve to the open position so as to initiate the purge cycle. Accordingly, solenoids and other complicated switching apparatus are not required. Further, the pressure actuatable member may itself move (eg. by resiliently expanding or by itself moving such as if it is a piston) to contact the purge valve. Accordingly, no electrical power supply is required to initiate the purging cycle.

10 According to the instant invention there is provided a concentrator for obtaining an enriched stream of a first fluid from a stream containing the first fluid and at least one second fluid, the concentrator comprising:

- 15 (a) a pressurizable adsorption zone having an inlet port for introducing the fluid stream to the adsorption zone, the pressurizable adsorption zone operable to produce the enriched stream;
- (b) a pressurizable container for receiving at least a portion of the enriched fluid stream;
- 20 (c) a passageway extending between the pressurizable adsorption zone and the pressurizable container;
- (d) an enriched fluid outlet for delivering at least a portion of the enriched fluid stream downstream of the concentrator;
- 25 (e) a purge valve in flow communication with the pressurizable adsorption zone and moveable between a closed position and an open position in which the pressurizable adsorption zone is purged during a purging cycle; and,
- 30 (f) a mechanical displaceable member operably associated with the purge valve to move the purge

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~~opposed~~ sides of the pivot point). Thus, the second portion may be
operatively connected to the purge valve and the resilient member
may contact the first portion when in the actuating position. The
mechanical linkage may be another form of lever, a cam member or
5 the like.

In another embodiment, the purge valve is spaced from
and positioned outwardly (and preferably directly outwardly) from
the displaceable member and is contacted by the displaceable
member as the displaceable member moves to the actuating
10 position.

A The purge valve is preferably a mechanical valve and
more preferably is a pressure actuated ^{mechanical}~~mechanically~~ valve (such as a
spring loaded check valve).

In accordance with the instant invention, there is also
15 provided a pressure swing adsorption apparatus for producing an
enriched stream of a first fluid from a stream containing the first
fluid and at least one second fluid, the apparatus comprising:

(a) means for reversibly adsorbing the at least one
second fluid to produce the enriched stream;

20 (b) pressurizable storage means for receiving at least a
portion of the enriched stream;

(c) outlet means in flow communication with the
storage means for venting at least a portion of the
enriched stream from the apparatus;

25 (d) purging means for removing at least a portion of the
at least one second fluid from the means for reversibly
adsorbing the at least one second fluid during a purging
cycle; and,

30 (e) actuating means operably associated with the
purging means for actuating the purging cycle upon the
pressurizable storage means reaching a preset pressure.

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In accordance with the instant invention, there is also provided a method for producing an enriched fluid having an increased concentration of a first fluid from a stream containing the first fluid and at least one second fluid comprising the steps of:

- 5 (a) the step of introducing the stream into a vessel containing a member for adsorbing the at least one second fluid;
- (b) the step of pressurizing the vessel for a time sufficient for the member to adsorb at least a portion of
- 10 the second fluid to produce the enriched fluid;
- (c) the step of cyclically passing the enriched fluid to a pressurizable container to pressurize the pressurizable container; and,
- 15 (d) the step of driving a member by the pressure in the pressurizable container to commence a purging cycle of the vessel when the pressurizable container reaches a preset pressure.

In one embodiment, the member mechanically drives an actuator of a purge valve to commence the purging cycle and the

20 method further comprises automatically commencing the purging cycle when the pressurizable container reaches a preset pressure.

In another embodiment, the member is biased to a first position and mechanically drives an actuator of a purge valve to commence the purging cycle when in a second position and the

25 method further comprises moving the member to contact the actuator due to the pressure increase in the pressurizable container.

In another embodiment, the member comprises a resilient member and the method further comprises the step of deforming the resilient member by the pressure in the pressurizable

30 container to commence the purging cycle.

In accordance with the instant invention, there is also

provided a method for producing an enriched fluid having an increased concentration of a first fluid from a stream containing the first fluid and at least one second fluid comprising:

- 5 (a) introducing the stream into a vessel containing an adsorbent for adsorbing the at least one second fluid;
- (b) pressurizing the vessel for a time sufficient for the adsorbent to adsorb at least a portion of the second fluid to produce the enriched fluid and venting enriched fluid from the vessel; and,
- 10 (c) using the enriched fluid vented from the vessel to ^{pressurize a} ~~pressurizing an~~ member to commence a purge cycle of the adsorbent.
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In one embodiment, the member mechanically drives an actuator of a purge valve to commence the purging cycle and the method further comprises automatically commencing the purge cycle when the pressure of the enriched fluid moves the member by a preset amount.

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In another embodiment, the member is biased to a first position and mechanically drives an actuator of a purge valve to commence the purging cycle when in a second position and the method further comprises moving the member to contact the actuator due to the pressure of the enriched fluid.

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In another embodiment, the member comprises a resilient member and the method further comprises the step of deforming the resilient member by the pressure of the enriched fluid to commence the purging cycle.

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It will be appreciated that, according to the instant invention, a concentrator, and in a preferred embodiment an oxygen concentrator, may be designed wherein a source of pressurized gas (eg. air) which is fed to the adsorption zone is the driving source of the entire apparatus. Accordingly, the resultant

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device, which uses only an external motive force, may be manufactured as a lightweight reliable unit.

In accordance with the instant invention, the apparatus may be designed to trigger the end of the purging cycle and thereby
5 commence the pressurization or charging or adsorption cycle as the member contracts to a pre-determined position. This position may be pre-determined based upon the volume of the adsorption zone and the time required to complete the purging cycle as well as the flow rate of enriched gas from the contactor.

10 In accordance with the instant invention, the apparatus may be designed to trigger the end of the adsorption cycle (i.e. the end of the pressurization of the vessel wherein enriched air is vented from the vessel), the beginning of the venting cycle (i.e. the beginning of venting enriched air from the vessel), the end of the
15 venting cycle (i.e. the end of the step of venting enriched air from the vessel), the beginning of the purge cycle (i.e. wherein purge air is introduced to the vessel to purge the vessel) and the end of the purge cycle (i.e. wherein the flow of purge air to the vessel is terminated and the adsorption cycle recommences) using essentially
20 only the pressure of the stream fed to the vessel.

Further, the apparatus is energy efficient since the timing of these cycles is based upon the actual completion of a cycle (i.e. the expansion or contraction of a pressure displaceable member) as opposed to ^{an} ~~a~~ electronic timing means which would initiate a cycle
25 regardless of the concentration of the enriched gas exiting the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other advantages of the instant invention
30 will be more fully and particularly understood in connection with the following description of a preferred embodiment of the

invention in which:

Figure 1 is a view illustrating in diagrammatic form a single stage concentrator according to the instant invention.

Figure 2 is an alternate embodiment of the concentrator of Figure 1.

Figure 3 is a second alternate embodiment of the concentrator of Figure 1; and,

Figure 4 is a third alternate embodiment of the concentrator of Figure 1.

DESCRIPTION OF PREFERRED EMBODIMENT

Concentrator 10 comprises inlet passage 12, outlet passage 14, adsorption zone 16 and a container 18. Passageway 20 extends between adsorption zone 16 and container 18.

Adsorption zone 16 may be of any particular construction which is known in the art for pressure swing adsorption apparatus. As shown in Figure 3, the adsorption zone 16 may comprise a vessel distinct from container 18 or it may be contained in the same housing as container 18 (see Figures 1, 2 and 4). Adsorption zone 16 is subjected to an increased pressure during which a selected fluid is adsorbed into adsorption media provided in adsorption zone 16 leaving a fluid having an increased concentration of the remaining ~~(unadsorbed)~~ ^{unadsorbed} fluids in adsorption zone 16. It will be appreciated that adsorption zone 16 may comprise a bed containing the adsorbent material through which the fluid flows as it passes through adsorption zone 16. The adsorbent may be discrete particles which are positioned between porous material 17 which functions to retain the adsorbent in adsorption zone 16.

The fluid may be a liquid or a gas. If the fluid is a liquid, then concentrator 10 may be used, for example, to selectively remove an impurity from a liquid stream (eg. the fluid selectively

adsorbed into carbon) such as water or a pesticide. The concentrator may also be used for pressure swing fractional distillation.

In a preferred embodiment, the fluid is a gas and, more preferably, the concentrator is an oxygen concentrator. The following description is based upon the use of concentrator 10 as an oxygen concentrator; however, the concentrator may be used for other pressure swing operations of fluids.

If concentrator 10 is an oxygen concentrator, then the feed gas which is introduced into adsorption zone 16 via inlet passage 12 comprises an oxygen containing gas and, more preferably, air. The adsorbent material in adsorption zone 16 accordingly comprises a material which selectively adsorbs nitrogen (the largest constituent of air) thereby leaving air containing an enriched level of oxygen in adsorption zone 16. Such adsorbent material are known in the art. Examples of such material are zeolites and, in a particularly preferred embodiment, the adsorbent is clinoptilolite.

It will be appreciated that, in an alternate embodiment, the desired product may be the fluid adsorbed onto the adsorbent media. In such a case, the gas produced during the purge cycle could be fed to a container or other apparatus as may be desired.

The remaining part of this description of the preferred embodiment is premised upon concentrator 10 including an adsorbent to remove nitrogen from air thereby producing a stream of oxygen enriched air. It is to be understood that the feed gas stream fed to adsorption stream 16 may comprise at least any two gases and the adsorbent material may be selected to adsorb the one or more of such gases leaving a gas stream having an enhanced concentration of the remainder of such gases.

Adsorption zone 16 operates under pressure. Accordingly, means is provided to raise adsorption zone 16 to the desired pressure. In the preferred embodiment, inlet passage 12 is

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connected in flow communication to pump 19 which feeds pressurized air (eg. at a pressure of 3 to 30 psig, preferably from 5 to 15 psig) to inlet passage 12. It will be appreciated that, in an alternate embodiment, a compressor or other means may be provided as part of apparatus 10 to feed an air stream into adsorption zone 16 and to pressurize adsorption zone 16 to the required pressure. The exact pressure which is required for the adsorption media to adsorb the targeted gas, and the length of the adsorption cycle, will depend on the thermodynamics of the adsorption media.

10 In order to pressurize adsorption zone 16, adsorption zone 16 is capable of being sealed so that it will be pressurized, e.g. via the gas entering through inlet passage 12. In Figure 1, apparatus 10 is provided with a bulkhead 22 having a check valve 24 provided therein. Further, passageway 20 is in flow communication with
15 passageway 26 which is in flow communication with purge valve 28. When valves 24 and 28 are in the closed position, as shown in Figure 1, adsorption zone 16 is sealed allowing the adsorbent positioned therein to selectively adsorb nitrogen.

Valve 24 may be any member which is moveable
20 between a first position in which adsorption zone 16 is isolated from container 18 and an open position in which adsorption zone 16 and container 18 are in flow communication. Further, valve 24 may be positioned at any point between adsorption zone 16 and container 18. For example, in the embodiment shown in Figure 3, adsorption
25 zone 16 and container 18 are in flow communication via passageway 20. Valve 24 may be positioned at any point between first and second ends 30 and 32 of passageway 20.

While adsorption zone 16 is undergoing the adsorption portion of the cycle, adsorption zone 16 is sealed
30 sufficiently such that adsorption zone 16 will be raised to the required pressure. It will be appreciated that valve 24 may allow

some gas to exit therethrough so as to provide a more continuous flow of gas through outlet passage 14. Preferably, no gas flow out of adsorption zone 16 is permitted during this part of the method. Accordingly purge valve 28 is preferably in the fully closed position shown in Figure 1 and valve 24 is preferably in the fully closed position shown in Figure 1. Adsorption zone 16 is thus isolated so as to allow pressure to build up therein. Due to the inflow of air through inlet passage 12, pressure will build up in adsorption zone 16 and nitrogen will be adsorbed in the adsorbent media.

Based upon the volume of adsorption zone 16, the adsorption characteristics of the adsorbent in adsorption zone 16 and the rate of air input into adsorption zone 16, the length of time required to achieve the desired concentration of oxygen in the free gas in adsorption zone 16 may be calculated. Further, a person skilled in the art will be able to determine the pressure at which this desired oxygen concentration will be achieved.

Any valve mechanism (either mechanically or electrically operated) may be used for valve 24. Preferably, valve 24 is a pressure actuated member which will open to bring adsorption zone 16 into flow communication with container 18 when adsorption zone 16 reaches the pressure at which the required oxygen concentration will have been achieved (eg. a check valve). One advantage of this approach is that valve 24 may open, and the adsorption cycle therefore terminate, when a desired preset pressure (which may be determined from the desired oxygen concentration of the enriched gas) is achieved. Thus no sensors are required to monitor the progress of the adsorption cycle. The adsorption cycle automatically terminates when the requisite pressure is reached. Preferably, valve 24 is a mechanical member (eg. valve member 34) which is biased (eg. by an elastomeric member, a spring 36 or the like) to the closed position and which will open when the pressure

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A upstream thereof (i.e. in adsorption ^{zone} 16 and in passageway 20) reaches a preset pressure (which may be the pressure at which the desired concentration of oxygen is achieved in the free gas in adsorption zone 16).

5 When valve 24 is in the open position, oxygen enriched air will pass from adsorption zone 16 through passageway 20 and into container 18. Outlet passage 14 is in flow communication with container 18. When valve 24 is in the open position, outlet passage 14 is also, indirectly, in flow communication
10 with adsorption zone 16.

In a preferred embodiment, outlet passage 14 has an aperture 38 which is open at all times when concentrator 10 is in operation. Aperture 38 is preferable of a pre-set opening size so as to provide a generally continuous flow of oxygen enriched air through
15 outlet passage 14 while oxygen enriched air is flowing into container 18. To this end, outlet passage 14 preferably has a reduced flow rate of gas therethrough than the flow rate of air into adsorption container 18 via valve 24. This may be achieved by providing flow restrictors 40 to create aperture 38. It will be appreciated that
20 decreasing the size of passageway 14 may achieve a similar result.

It will also be appreciated that, if desired, aperture 38 may have a variable opening size so as to vary the flow rate of oxygen enriched air through outlet passage 14. Further, aperture 38 may be operable so as to seal outlet passage 14 (or alternately a valve
25 to close outlet passage 14 may be provided). This may be desirable if, for example there is back pressure from downstream equipment.

The flow rate of oxygen enriched gas from outlet passage 14 is less than the flow rate of oxygen enriched gas into container 18 via valve 24. Accordingly, the pressure in container 18
30 will build up due, for example, to the size of aperture 38 which is created by flow restrictors 40.

Passageway 26 is selectively connectable in flow communication with a low pressure zone (eg. the atmosphere) via purge valve 28. As shown in Figure 1, purge valve 28 is positioned between the downstream end of passageway 26 and header space 42.

5 Space 42 may be vented to the atmosphere via outlet passageway 44. Accordingly, when purge valve 28 is in the open position, gas may flow through passageway 26, through purge valve 28, through header space 42, through passageway 44 to the atmosphere.

As shown in Figure 3, passageway 20 is in flow communication via check valve 24 with container 18 and outlet passage 14 (which is provided external to container 18). When a sufficient pressure builds up in adsorption zone 16, check valve 24 opens permitting oxygen enriched gas to pass through passageway 20 into container 18 and, simultaneously, out of outlet passageway 14 via, for example, aperture 38. In this case, purge valve 28 is provided in the housing of adsorption zone 16. In this embodiment, when purge valve 28 is open, pressurized air will pass from adsorption zone 16 through purge valve 28 to, for example, the atmosphere thus reducing the pressure in adsorption zone 16 and causing check valve 24 to move to the closed position.

Referring to Figure 1, container 18 has a pressure displaceable member 46 associated therewith. Pressure displaceable member 46 may be any member which moves outwardly relative to the interior of container 18 as pressure increases in container 18. For example, as shown in Figure 1, pressure displaceable member 46 may be a resilient member (e.g. an elastomeric diaphragm) which expands outwardly (as represented by the dotted outline shown in Figure 1) as the pressure increases in container 18. When sufficient pressure has built up in container 18, displaceable member 46 deforms to expand to a position such that actuator 48 (which is provided as part of displaceable member 46) contacts actuator 50 of

purge valve 28. A further increase in pressure in container 18 will cause actuator 48 to displace actuator 50 such that purge valve 28 will move to the open position. Once this occurs, the purging cycle will commence.

5 During the purge cycle, pressurized air is preferably introduced into adsorption zone 16 via pump 19. As purge valve 28 is open, air will pass from adsorption zone 16 through passageways 20 and 26 to exit the contactor via purge valve 28 and passageway 44. This will reduce the pressure exerted on valve member 34 of valve 10 24 thus closing valve 24 and sealing container 18 from flow communication with adsorption zone 16. Container 18 may continue to depressurize by providing oxygen enriched air to passageway 14 via aperture 38. As the pressure in container 18 decreases, ^{displaceable} ~~deformable~~ member ⁴⁶ ~~36~~ returns to its depressurized state 15 (shown in solid line in Figure 1) thus permitting valve 28 to move to the closed position. Once purge valve 28 is closed, the pressurization cycle of adsorption zone 16 may recommence. It will be appreciated that if a two way valve is used for valve 24, some of the gas in container 18 may flow back into adsorption zone 16 to 20 assist in its purge cycle.

At the end of the purge cycle, the pressure in adsorption zone 16 may have been reduced to a pressure from about atmosphere to about 5 psig. Thus concentrator 10 may operate with a pressure swing between the peak pressure of the adsorption cycle 25 and the low pressure of the purge cycle of 5 to 15 psig and, preferably 10 psig.

Displaceable member 46 may take a variety of forms. For example, as shown in Figure 1, it may be a resilient deformable member. As such, it may expand and contract to its at rest position 30 repeatedly as container 18 is cyclically pressurized. As such, a resilient diaphragm may be affixed to the upper surface of bulk head

A further advantage of the instant invention is that the purge cycle is automatically completed when container 18 depressurizes by an amount such that displaceable member 18 withdraws towards container 18 by an amount sufficient to allow actuator 50 to move to the closed position.

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Referring to Figure 3, an alternate embodiment is shown in which container 18 is positioned below adsorption zone 16. In this embodiment, purge valve 28 is positioned above pressure displaceable member 46. During the purge cycle, pressurized air is passed via inlet passageway 12 through adsorption zone 16 and is vented into the atmosphere via purge valve 28.

Referring to Figure 4, a further alternate embodiment is shown. In this embodiment, purge valve 28 comprises a valve member 56 which sealing engages the distal end of passageway 26. Pressure displaceable member 46 is operably connected to valve member 56 via pivot member 58. Pivot member 58 has a first arm 60 and a second arm 62 positioned on opposed sides of pivot axle 64. The outward displacement of pressure displaceable member 46 causes first arm 60 to move upwardly as indicated by arrow A in Figure 4. Pivot member 58 accordingly pivots about pivot axle 64 causing second arm 62 to move in the direction indicated by arrow B in Figure 4 thus withdrawing valve member 56 from the distal end of passageway 26 thus permitting air to exit contactor 10. Pivot axle 64 may be mounted to, e.g. housing 66. Accordingly, pressure displaceable member 46 indirectly actuates purge valve 28.

By constructing a concentrator according to the instant invention, a repeatable cycle can be achieved using simple mechanical feedback (i.e. the interaction between purge valve 28 and pressure displaceable member 46). Pressure displaceable member ~~26~~⁴⁶ may be an expandable member (e.g. a resilient member) which will expand to actuate the purge valve due to a pressure increase in container 18. In an alternate embodiment, it may be a movable member such as a piston which moves outwardly from container 18 due to an increase in pressure in container 18. Pressure displaceable member 46 is biased to an at rest (depressurized) position by a biasing means which may be a spring or the inherent resiliency of a resilient diaphragm. Thus, by using simple mechanical linkages and movable or expandable elements, a concentrator having a simple rugged construction may be produced.

Another advantage of the instant invention is that the outward displacement of pressure displacement member 46 is used to time the purge cycle of adsorption zone 16. Accordingly,

electronic timers or concentration sensors are not required to provide input to a controller to determine when the purge cycle should be commenced or terminated.

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